27. (Amended) The arrangement according to claim 26, wherein said processor is configured such that said regulating variable or a quantity definable from said regulating variable is displayed to a traffic participant on said display.

28. (Amended) A traffic guidance system comprising a plurality of arrangements according to claim 26.

REMARKS

The present Amendment revises the specification and claims to conform to United States patent practice, before examination of the present PCT application in the United States National Examination Phase. Pursuant to 37 CFR 1.125 (b), applicants have concurrently submitted a substitute specification, excluding the claims, and provided a marked-up copy. All of the changes are editorial and applicant believes no new matter is added thereby. The amendment, addition, and/or cancellation of claims is not intended to be a surrender of any of the subject matter of those claims.

Early examination on the merits is respectfully requested.

Submitted by,

Mark Bergner (Reg. No. 45,877)

Mark Bergner
Schiff Hardin & Waite
Patent Department
6600 Sears Tower
233 South Wacker Drive
Chicago, Illinois 60606-6473
(312) 258-5779
Attorneys for Applicant

Appendix A
Mark Ups for Claim Amendments

This redlined draft, generated by CompareRite (TM) - The Instant Redliner, shows the differences between -
original document : Q:\DOCUMENTS\YEAR 2000\P001938-LENZ-REGULATING VARIABLE\ORIGINAL CLAIMS.DOC
and revised document: Q:\DOCUMENTS\YEAR 2000\P001938-LENZ-REGULATING VARIABLE\AMENDED CLAIMS.DOC

CompareRite found 131 change(s) in the text

Deletions appear as Overstrike text surrounded by []
Additions appear as Bold-Underline text

1. [~~Method~~]**(Amended) A method** for determining [~~at least one~~] **a** regulating variable of a technical system that is described with a predetermined model description in a predetermined space [~~that comprises the following steps:~~] **comprising the steps of:**

[~~B transformation of the~~] **transforming said** model description into a sub-space of [~~the~~] **said** space;

[~~B determination of~~] **determining** a regulator model description [~~form~~] **from** the transformed model description upon employment of a prescribable non-linear regulator model;

[~~B back-transformation of the~~] **back-transforming said** regulator model description into [~~the~~] **said** space of [~~the~~] **said** model description; **and**

determining said [~~B determination of the~~] regulating variable **of said technical system** upon employment of [~~the~~] **said** back-transformed regulator model description.

2. [~~Method~~]**(Amended) The method** according to claim 1, [~~whereby a plurality of~~]**further comprising the step of determining additional** regulating variables [~~are determined.~~]**.**

~~[3. Method]~~ **3. (Amended) The method** according to claim 1 ~~[or 2, utilized for regulating the technical system.]~~**, further comprising the step of regulating said technical system with said regulating variable.**

~~[4. Method according to one of the claims 1 through 3, whereby the]~~ **4. (Amended) The method according to claim 1, wherein said** technical system describes a traffic flow.

5. ~~[Method]~~**(Amended) The method** according to claim 4, ~~[whereby the]~~ **wherein said** traffic flow is described by the following relationship:

$$Veq(\rho) = \sum_{i=1}^{2} w_i \left(1 - \frac{\rho}{\rho_i}\right)^{(l_i - 1)\frac{1}{(1 - m_i)}} \qquad \text{(Equation 1)}$$

~~[with:]~~ **where:**

w_i or~~[, respectively, ñi :]~~ **ρ_i is a** freely selectable imaging parameter**,**

l_i or~~[, respectively, mi :]~~ **m_i is a** freely selectable imaging parameter**,**

i ~~[:]~~ **is a** run variable**,**

V_{eq} is an ~~[Veq or, respectively, ñ :]~~ equilibrium velocity ~~[or, respectively,]~~**,**

and

ρ is a vehicle density.

6. ~~[Method]~~**(Amended) The method** according to claim 4 ~~[or 5, whereby the]~~**, wherein said** traffic flow is described by a continuity equation.

7. ~~[Method]~~**(Amended) The method** according to claim 6, ~~[whereby the]~~ **wherein said** continuity equation comprises the following relationship:

$$\frac{d}{dt}\rho + \frac{d}{dx}q = \frac{d}{dt}\rho + \frac{d}{dx}(\rho v) = 0 \qquad \text{(Equation 2)}$$

~~[with:]~~ **where:**

q ~~[:]~~ **is a** traffic flow**,**

d/dt ~~[or, respectively, d/dx :]~~ **is** a partial ~~[derivation]~~ **derivative** according to ~~[the time t or, respectively,]~~ **a time t, and**

d/dx is a partial derivative according to ~~[the]~~ **a** location x.

8. ~~[Method]~~**(Amended) The method** according to ~~[one of the claims 4 through 7, whereby the]~~ **claim 4, wherein said** traffic flow is described by an acceleration equation.

9. ~~[Method]~~**(Amended) The method** according to claim 8, whereby the acceleration equation comprises the following relationship:

$$\frac{d}{dt}v + v\frac{d}{dx}v = \frac{1}{\tau}(V_{eq}(\rho) - v) - \frac{c_0^2 d\rho}{\rho dx} + \frac{\eta_0 d^2 v}{\rho dx^2}$$

(Equation 3)

~~[with:~~

~~ô : relaxation time~~

~~c02 : velocity variance~~

~~ç0 : viscosity constant~~

~~d/dt, d/dx, d2/dx2 : a partial derivation according to the time t or, respectively, a partial first and a partial second derivation according to the location x.~~

~~10. Method according to one of the claims 1 through 9, whereby the transformation is implemented in that dimensions of the space of the technical system are returned onto a dimension of the sub-space of the space.~~

~~11. Method according to one of the claims 1 through 10, whereby the]~~ **where:**

τ is a relaxation time,

c_0^2 is a velocity variance,

η_0 is a viscosity constant,

d/dt is a partial derivative according to a time t,

d/dx is a partial first derivative according to a location x, and

d^2/dx^2 is a partial second derivative according to said location x.

<u>10. (Amended) The method according to claim 1, further comprising the step of returning dimensions of said space of said technical system onto a dimension of said sub-space of said space.</u>

<u>11. (Amended) The method according to claim 1, wherein said</u> non-linear regulator model describes a non-linear, structurally variable regulator.

12. ~~[Method]~~**<u>(Amended) The method</u>** according to claim 11, ~~[whereby]~~ **<u>wherein</u>** a method of an equivalent regulation is utilized for the design of the non-linear, structurally variable regulator.

13. ~~[Method]~~**<u>(Amended) The method</u>** according to claim 1 ~~[through 12, whereby the]~~**<u>, further comprising the step of displaying, to a traffic participant, said</u>** regulating variable ~~[and/or]~~ **<u>or</u>** a quantity definable from ~~[the]~~ **<u>said</u>** regulating variable ~~[is displayed to a traffic participant.]~~<u>.</u>

~~[14. Arrangement]~~ **<u>14. (Amended) An arrangement</u>** for determining ~~[at least one]~~ **<u>a</u>** regulating variable of a technical system that is described with a predetermined model description in a predetermined space, said arrangement comprising a processor that is configured ~~[such that the following steps can be implemented:]~~ **<u>to:</u>**

~~[B transformation of the]~~ **<u>transform said</u>** model description into a sub-space of ~~[the]~~ **<u>said</u>** space;

~~[B determination of]~~ **<u>determine</u>** a regulator model description ~~[form the]~~ **<u>from said</u>** transformed model description upon employment of a prescribable non-linear regulator model;

~~[B back-transformation of the]~~ **<u>back-transform said</u>** regulator model description into ~~[the]~~ **<u>said</u>** space of ~~[the]~~ **<u>said</u>** model description;

~~[B determination of the]~~ **<u>determine said</u>** regulating variable upon employment of ~~[the]~~ **<u>said</u>** back-transformed regulator model description.

15. ~~[Arrangement]~~**(Amended) The arrangement** according to claim 14, ~~[whereby the]~~ **wherein said** processor is configured such that a plurality of regulating variables can be determined.

16. ~~[Arrangement]~~**(Amended) The arrangement** according to claim 14 ~~[or 15, whereby the]~~**, wherein said** processor is configured for regulating ~~[the]~~ **said** technical system.

17. ~~[Arrangement]~~**(Amended) The arrangement** according to ~~[one of the claims 14 through 16, whereby the]~~ **claim 14, wherein said** processor is configured such that ~~[the]~~ **said** technical system describes a traffic flow.

18. ~~[Arrangement]~~**(Amended) The arrangement** according to claim 17, ~~[whereby the]~~ **wherein said** processor is configured such that ~~[the]~~ **said** traffic flow is described by ~~[the following]~~ **a** relationship:

$$V_{eq}(\rho) = \sum_{i=1}^{2} w_i \left(1 - \frac{\rho}{\rho_i}\right)^{(l_i - 1)\frac{1}{(1 - m_i)}} \qquad \text{(Equation 1)}$$

~~[with:]~~ **where:**

w_i or~~[, respectively, ñi :]~~ **ρ_i is a** freely selectable imaging parameter**,**

l_i or~~[, respectively, mi :]~~ **m_i is a** freely selectable imaging parameter**,**

i ~~[:]~~ **is a** run variable

V_{eq} ~~[or, respectively, ñ :]~~ **is an** equilibrium velocity ~~[or, respectively,]~~**, and**

ρ is a vehicle density.

19. ~~[Arrangement]~~**(Amended) The arrangement** according to claim 17 ~~[or 18, whereby the]~~**, wherein said** processor is configured such that ~~[the]~~ **said** traffic flow is described by a continuity equation.

20. ~~[Arrangement]~~**(Amended) The arrangement** according to claim 19, ~~[whereby the]~~ **wherein said** processor is configured such that ~~[the]~~ **said** continuity equation comprises ~~[the following]~~ **a** relationship:

$$\frac{d}{dt}\rho + \frac{d}{dx}q = \frac{d}{dt}\rho + \frac{d}{dx}(\rho v) = 0 \qquad \text{(Equation 2)}$$

~~[with:]~~ **where:**

q ~~[:]~~ **is a** traffic flow**,**

d/dt is ~~[d/dt or, respectively, d/dx :]~~ a partial ~~[derivation]~~ **derivative** according to ~~[the time t or, respectively,]~~ **a time t, and**

d/dx is a partial derivative according to ~~[the]~~ **a** location x.

21. ~~[Arrangement]~~**(Amended) The arrangement** according to ~~[one of the claims 17 through 20, whereby the]~~ **claim 17, wherein said** processor is configured such that ~~[the]~~ **said** traffic flow is described by an acceleration equation.

22. ~~[Arrangement]~~**(Amended) The arrangement** according to claim 21, ~~[whereby the]~~ **wherein said** processor is configured such that ~~[the]~~ **said** acceleration equation comprises ~~[the following]~~ **a** relationship:

$$\frac{d}{dt}v + v\frac{d}{dx}v = \frac{1}{\tau}(V_{eq}(\rho) - v) - \frac{c_0^2 d\rho}{\rho dx} + \frac{\eta_0 d^2 v}{\rho dx^2}$$

(Equation 3)

~~[with:]~~ **where:**

τ ~~[:]~~ **is a** relaxation time**,**

c_0^2 ~~[:]~~ **is a** velocity variance

η_0 ~~[:]~~ **is a** viscosity constant

d/dt~~[, d/dx, d2/dx2 : a partial derivation according to the time t or, respectively, a partial first and a partial second derivation according to the location x.~~

~~23. Arrangement according to one of the claims 14 through 22, whereby the]~~ **is a partial derivative according to a time t,**

d/dx is a partial derivative according to a location x, and
d^2/dx^2 is a partial second derivative according to said location x.

23. (Amended) The arrangement according to claim 14, wherein said processor is configured such that ~~[the]~~ **said** transformation can be implemented in that dimensions of ~~[the]~~ **said** space of ~~[the]~~ **said** technical system are returned onto a dimension of ~~[the]~~ **said** sub-space of ~~[the]~~ **said** space.

24. ~~[Arrangement]~~**(Amended) The arrangement** according to ~~[one of the claims 14 through 23, whereby the]~~ **claim 14, wherein said** processor is configured such that ~~[the]~~ **said** non-linear regulator model describes a non-linear, structurally variable regulator.

25. ~~[Arrangement]~~**(Amended) The arrangement** according to claim 24, ~~[whereby the]~~ **wherein said** processor is configured such that a method of equivalent regulation is utilized for ~~[the design of the]~~ **designing said** non-linear, structurally variable regulator.

26. ~~[Arrangement]~~**(Amended) The arrangement** according to ~~[one of the claims 14 through 24,]~~ **claim14, further** comprising a display ~~[means]~~.

27. ~~[Arrangement]~~**(Amended) The arrangement** according to ~~[one of the claims 14 through 26, whereby the]~~ **claim 26, wherein said** processor is configured such that ~~[the]~~ **said** regulating variable ~~[and/or]~~ **or** a quantity definable from ~~[the]~~ **said** regulating variable is displayed to a traffic participant **on said display**.

28. A ~~[set of]~~ **traffic guidance system comprising** a plurality of arrangements according to claim 26 ~~[or 27 utilized in a traffic guidance system]~~.

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SPECIFICATION

TITLE

METHOD AND ARRANGEMENT FOR DETERMINING A REGULATING VARIABLE OF A TECHNICAL SYSTEM THAT IS DESCRIBED WITH A PREDETERMINED MODEL DESCRIPTION IN A PREDETERMINED SPACE

BACKGROUND OF THE INVENTION

Field of the Invention

The invention is directed to a computer-supported determination of a regulating variable of a technical system that is described with a predetermined model description in a predetermined space.

Description of the Related Art

Use of [~~It is known from [1, 2, 3] to employ~~] a continuous model for the description of a system **is known from Kerner, B.S., et al. "Structure and parameters of clusters in traffic flow", Phys. Rev. E50 (1), pp. 54-83, 1994 (Kerner); Kühne, R., Pal, S.K., "Straßenverkehrsveeinflussung und Physik der Phasenübergänge, Physik in unserer Zeit, Volume 15, No. 3, pp. 84-92, 1984 (Kühne); and Zackor, H., et al., "Untersuchungen des Verkehrsablaufs im Bereich der Leistungsfähigket und bei instabilem Fluß", Forschung Straßenbau und Straßenverkehrstechnik, No. 524, 1988 (Zackor)**. The following state quantities are employed for describing a state of the system:

B traffic flow velocity v**;**

B vehicle density ρ (ρ = plurality of vehicles Fz/km)**; and**

B traffic flow q (q = plurality of vehicles Fz/h[]], q = v * ρ).

~~[Further]~~ **Furthermore,** a means is known, for example, a conductor loop worked into a lane **of a road having traffic** that is coupled to a counter and to an interpretation unit, with which the state quantities (v, ρ, q) of the system of the traffic flow can be measured.

Proceeding from a static relationship between an equilibrium velocity V_{eq} of the traffic flow (V_{eq} = static traffic flow velocity in a stationary state of the traffic flow) and the vehicle density ~~[ρ]~~**Ñ**, the model known from ~~[[1, 2, 3]]~~ **Kerner, K¨hne, and Zackor** describes the traffic flow in an equilibrium **stateThe** ~~[state. The]~~ following relationship applies:

$$V_{eq}(\rho) = \sum_{i=1}^{2} w_i \left(1 - \frac{\rho}{\rho_i}\right)^{(l_i - 1)\frac{1}{(1 - m_i)}} \quad \text{(Equation 1)}$$

with:

w_i or, respectively, ρ_i : freely selectable imaging parameter

l_i or, respectively, m_i : freely selectable imaging parameter

i : run variable

V_{eq} or, respectively, ρ :equilibrium velocity or, respectively, vehicle density.

It is also known from ~~[[1, 2, 3]]~~ **Kerner, Kóhne, and Zackor** that both the traffic flow velocity v as well as the vehicle density ρ vary dependent on a location x and on a time t according to the relationship v = v(x, t) or, respectively, ρ = ρ (x, t) [x: location variable, t: time variable].

For describing this dynamic **aspect**, the model is expanded by a continuity equation (Equation 2) and an acceleration equation (Equation 3).

The continuity equation (Equation 2), corresponding to the relationship

$$\frac{d}{dt}\rho + \frac{d}{dx}q = \frac{d}{dt}\rho + \frac{d}{dx}(\rho v) = 0 \quad \text{(Equation 2)}$$

with:

q : traffic flow

d/dt or, respectively, d/dx : a partial ~~[derivation]~~ **derivative** according to the time t or, respectively, according to the location x,

describes the ~~[dynamic]~~ **dynamics** of the traffic flow under the condition that the traffic flow exhibits a continuous flow without ~~[and]~~ **an** entry and departure of a vehicle from the system.

The acceleration equation (Equation 3) describes the dynamic **aspect** of the traffic flow outside the equilibrium state established by the static equilibrium velocity according to Equation 1, using the following relationship:

$$\frac{d}{dt}v + v\frac{d}{dx}v = \frac{1}{\tau}(V_{eq}(\rho) - v) - \frac{c_0^2 d\rho}{\rho dx} + \frac{\eta_0 d^2 v}{\rho dx^2}$$

(Equation 3)

with:

τ : relaxation time

c_0^2 : velocity variance

η_0 : viscosity constant

d/dt, d/dx, d^2/dx^2 : a partial ~~[derivation]~~ **derivative** according to the time t or, respectively, a partial first and a partial second derivation according to the location x.

Proceeding from the description of the traffic flow by such a model, a stability analysis of the model supplies characteristic properties of the traffic flow described by the model.

A local stability analysis of the above-presented model by linearization around a stationary operating point (v_0, ρ_0) shows that the unregulated traffic flow according to the model exhibits an unstable behavior for a vehicle density ρ in a range ~~[[]~~**from** approximately 20 Fz/km ~~[-]~~**to** approximately 50 Fz/km~~[]]~~. A disturbance of the traffic flow increases and leads to conditions ~~[to be]~~ observed in real traffic situations such as~~[, for example,]~~ a suddenly occurring standstill of the traffic flow (jam) or a ~~[Astop]~~**“stop**-and-go ~~[wave@]~~**wave”**.

The system exhibits a stable behavior in the region of the vehicle density ρ~~[[]~~**, where** $\rho < 20$ Fz/km~~[]]~~, and in the region of the vehicle density ρ~~[[]~~**, where** $\rho > 50$ Fz/km~~[]]~~.

The following ranges are distinguished **from one another**:

$\rho < 20$ Fz/km : low traffic, high speed, stable behavior

20 Fz/km $< \rho <$ 50 Fz/km unstable behavior, minor disturbances crop up

$\rho > 50$ Fz/km : high traffic volume, slowly moving traffic or jam, stable behavior.

It is also known to apply a method of control technology to a traffic flow model in order to [~~thus~~] assure a regulated and stable traffic flow in the overall state space of the traffic flow.

Realizing a control with a linear state return is known from [[~~4~~]~~. The~~] **Cremer, M. et al., AEinsatz regelungstechnischer Mittel zur Verbesserung des Verkehrsablaufs und Straíenverkehrstechnik, No. 307, 1980 (Cremer), which discusses the** traffic flow in a state [~~wherein~~] **in which** the traffic flow exhibits an unstable behavior can [~~thus~~] be stabilized and a uniform flow of the traffic is assured.

The linear approach from [[~~4~~]] **Cremer**, however, exhibits various disadvantages. [~~Thus, a~~] **A** stabilization of the traffic flow is only possible for a minor disturbance of the traffic flow or[~~, respectively,~~] only in a small area (Δv, $\Delta \rho$) of the state space (v, ρ, q) around the operating point (v_0, ρ_0) of the linearization. [~~Due, further,~~] **Furthermore, due** to a linear state return, the regulation supplies a regulating variable that, due to the size of its value, cannot be applied to the real traffic flow.

Various [~~method~~] **methods** of non-linear control technology are known from [[~~5~~]~~. It is also presented in [5] that~~] **Lenz, H., Berstecher, R., Lang, M., "Adaptive Sliding-Mode Control of the Absolute Gain", IFAC Nonlinear COntrol Systems Design Symposium, Enschede, Netherlands, 1988 (Lenz), which discusses** a structurally variable regulator [~~is~~] **being** used for regulating a non-linear system due to its ruggedness with respect to a malfunction. The method of equivalent control is applied in [[~~5~~]] **Lenz** for determining the parameters of the structurally variable regulator.

It is also known that a controlled traffic flow model can be utilized for regulating [~~the~~] **a** real traffic flow. To that end, state quantities of a real traffic situation are measured. These state quantities are applied to the control system, [~~whereby~~] **where** the control system determines a regulating variable such as[~~, for example,~~] the traffic flow velocity v_{rated}. Upon employment of a display [~~means~~] **device** such as[~~, for example~~] a changing traffic signal of a traffic guidance system,

this regulating variable~~[,]~~ **(**a rated velocity**,** according to the above example~~[,]~~**)** is prescribed for the traffic flow.

SUMMARY OF THE INVENTION

The invention is based on ~~[the problem of specifying]~~ **providing** a computer-supported method for determining a regulating variable of a technical system, ~~[whereby]~~ **where** the technical system is stabilized by the regulated system, and ~~[whereby]~~ **where** the regulating variable can be applied to the technical system. The problem is solved by ~~[the method according to patent claim 1 and by the arrangement according to patent claim 13.]~~ **a method for determining a regulating variable of a technical system that is described with a predetermined model description in a predetermined space comprising the steps of: transforming said model description into a sub-space of said space; determining a regulator model description from the transformed model description upon employment of a prescribable non-linear regulator model; back-transforming said regulator model description into said space of said model description; and determining said regulating variable of said technical system upon employment of said back-transformed regulator model description.**

~~[In the method according to patent claim 1]~~ **In the inventive method**, a regulating variable of a technical system is defined, that is described with a predetermined model description in a predetermined space. To that end, the model description is transformed into a sub-space of the space. In this sub-space, a regulator model description is determined from the transformed model description upon employment of a non-linear regulator model. This regulator model description is transformed back into the original space. The regulating variable is determined upon employment of the back-transformed regulator model description.

~~[The]~~ **Similarly, the** arrangement ~~[according to patent claim 13]~~ **associated with the inventive method** for determining a regulating variable of a technical system that is described with a predetermined model description in a predetermined space comprises a processor that is configured **to implement: transforming** ~~[such that the following steps can be implemented:~~

~~B transformation of~~] the model description into a sub-space of the space; **determining** [~~B determination of~~] a regulator model description [~~form~~] **from** the transformed model description upon employment of a prescribable non-linear regulator model; [

~~B~~] back-[~~transformation of~~] **transforming** the regulator model description into the space of the model description; **and determining** [~~B determination of~~] the regulating variable upon employment of the back-transformed regulator model description.

What the **above** method and the arrangement achieve is that a regulating variable of a technical system is determined, [~~whereby~~] **where** the controlled technical system stabilizes a disturbance, and that the regulating variable assumes such a value that the regulating variable can be applied to the real system underlying the technical system.

Advantageous developments of the invention [~~derive from the dependent claims~~] **are described below**.

It is advantageous in one development to utilize the invention for the control of the technical system. A disturbance of the technical system can [~~thus~~] be stabilized[~~,~~] so that the technical system exhibits a stable behavior in the entire state space (v, ρ, q).

In a further development of the invention, the technical system is a traffic flow. It is thus possible to regulate the traffic flow such that a uniform and disturbance-free state of the traffic flow is achieved.

In one development of the invention, it is advantageous to present the traffic flow on the basis of the following relationship:

$$Veq(\rho) = \sum_{i=1}^{2} w_i \left(1 - \frac{\rho}{\rho_i}\right)^{(l_i - 1)\frac{1}{(1 - m_i)}} \qquad \text{(Equation 1)}$$

[~~with~~] **where**:

w_i or, respectively, ρ_i : freely selectable imaging parameter

l_i or, respectively, m_i : freely selectable imaging parameter

i : run variable

V_{eq} or, respectively, ρ :equilibrium velocity or, respectively, vehicle density.

The above-presented relationship is a suitable model of the real system of the uniform traffic flow and is thus especially suited for the control of the system.

In order to take the location and/or time dependency of the state quantities of a traffic flow into consideration, it is advantageous as a development of the invention to describe the traffic flow with a continuity equation and/or an acceleration equation.

It is advantageous in a development of the invention to present the continuity equation with the following relationship:

$$\frac{d}{dt}\rho + \frac{d}{dx}q = \frac{d}{dt}\rho + \frac{d}{dx}(\rho v) = 0 \qquad \text{(Equation 2)}$$

~~[with]~~ **where**:

q : traffic flow

d/dt or, respectively, d/dx : a partial derivation according to the time t or, respectively, according to the location x,

and/or to present the acceleration equation with the following relationship:

$$\frac{d}{dt}v + v\frac{d}{dx}v = \frac{1}{\tau}(V_{eq}(\rho) - v) - \frac{c_0^2 d\rho}{\rho dx} + \frac{\eta_0 d^2 v}{\rho dx^2}$$

(Equation 3)

~~[with]~~ **where**:

τ : relaxation time

c_0^2 : velocity variance

η_0 : viscosity constant

d/dt, d/dx, d^2/dx^2 : a partial derivation according to the time t or, respectively, a partial first and a partial second derivation according to the location x.

The above-presented relationships represent a good model for the location and time dependency of the state quantities of the real system of the traffic flow and are thus especially suited for controlling the system.

In a development of the invention, an especially simple method derives when the transformation into the sub-space of the space is implemented in that a plurality of dimensions of the space of the ~~[space [sic] of the]~~ technical system are returned to a dimension of the sub-space.

It is especially advantageous in a development of the invention to describe the non-linear regulator model with a non-linear, structurally variable regulator. The ruggedness in view of a disturbance is thus enhanced, and a good control behavior is assured.

A method of an equivalent regulation is preferably utilized for the design of the non-linear, structurally variable regulator in a development of the invention due to the simple method.

It is especially advantageous to utilize the invention in the framework of a traffic guidance system since a uniform and stable traffic flow of the real system can thus be achieved. The regulating variable and/or a variable that can be defined from the regulating variable can be communicated to a traffic participant with the assistance of a display [~~means~~] **device** for this purpose.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments of the invention are shown in Figures 1 through 3 and are explained in greater detail below.

[~~Shown are:~~

]Figure 1 **is a** schematic illustration of a real system of a traffic flow;

Figure 2 **is a** schematic illustration of the development of a non-linear regulating system for the traffic flow system;

Figure 3 **is a flowchart illustrating** regulation of a real system, traffic flow.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 schematically shows a real system of a traffic flow. [

]Vehicles 102 are moved in a travel direction 106 by their respective drivers 103 on a monitored path segment 101 of a travel path. [

]State quantities of the system are measured at a predetermined location, a measuring point 104, within the monitored path segment 101. **These quantities are measured using** [~~To this end,~~] a conductor loop 105 **that** is worked into a lane 109[~~, this measuring the~~] **which measures a** plurality i_{Fz} of vehicles 102 that cross the measuring point 104 within a predetermined time span Δt and the respective velocity v_{iFz} of the vehicle 102 that crosses the measuring point 104.

The measured values (i_{Fz}, v_{iFz}) are transmitted to an evaluation unit 107 that is coupled to the conductor loop 105. [~~Dependent~~] **Depending** on the transmitted quantities, the evaluation unit 107 determines a guideline velocity v_{Rated} 108 that is communicated to the traffic participants upon employment of a traffic guidance system [~~1120~~] **110** that is coupled to the evaluation unit 107.

Figure 2 schematically shows the development of a non-linear regulating system for the traffic flow system.

1. Model Description of the Traffic Flow System in the State Space (Step 201)

The model description (step 201) of the traffic flow system in that state space ensues on the basis of:

$$Veq(\rho) = \sum_{i=1}^{2} w_i \left(1 - \frac{\rho}{\rho_i}\right)^{(l_i - 1)\frac{1}{(1 - m_i)}} \qquad \text{(Equation 1)}$$

[~~with~~] **where**:

w_i or, respectively, ρ_i : freely selectable imaging parameter

l_i or, respectively, m_i : freely selectable imaging parameter

i : run variable

V_{eq} or, respectively, ρ :equilibrium velocity or, respectively, vehicle density,

[~~whereby~~] **where**:

w_1 = 100 km/h or, respectively, w_2 = 10 km/h

ρ_1 = 100 Fz/km or, respectively, ρ_2 = 160 Fz/km

l_1 = 3.2 or, respectively, l_2 = 2

m_1 = 0.9 or, respectively, m_2 = 0 are set.

The following applies for a free velocity v_{free} in the limit value (ρ □ 0):

$v_{free} = w_1 + w_2$ = 110 km/h.

w_1 = 0 applies for $\rho > \rho 1$ in order to prevent a rise of the V_{eq} (ρ) relationship.

Taking the location and time dependency (x, t) of the state quantity velocity v = v(x, t) and the state quantity $\rho = \rho(x, t)$ into consideration ensues with continuity equation (Equation 2) and acceleration equation (Equation 3):

$$\frac{d}{dt}\rho + \frac{d}{dx}q = \frac{d}{dt}\rho + \frac{d}{dx}(\rho v) = 0 \qquad \text{(Equation 2)}$$

~~[with]~~ **where**:

q : traffic flow

d/dt or, respectively, d/dx : a partial derivation according to the time t or, respectively, according to the location x,

$$\frac{d}{dt}v + v\frac{d}{dx}v = \frac{1}{\tau}(V_{eq}(\rho) - v) - \frac{c_0^2 d\rho}{\rho dx} + \frac{\eta_0 d^2 v}{\rho dx^2}$$

(Equation 3)

~~[with]~~ **where**:

τ : relaxation time

c_0^2 : velocity variance

η_0 : viscosity constant

d/dt, d/dx, d^2/dx^2 : a partial derivation according to the time t or, respectively, a partial first and a partial second derivation according to the location x.

~~[whereby]~~ **where**:

τ_0 = 6 s or, respectively, c_0 = 13.31 m/s or, respectively, η_0 = 59.33 m/s is set.

The effect of a speed limit on the traffic flow is described by a scaling of Equation 1:

$V_{eq}(\rho, u) = (l+1)V_{eq}(\rho)$ (Equation 4)

with:

u : regulator output quantity

$uV_{eq}(\rho)$: regulating variable

vfree(l+u) : displayed maximum speed

2. Transformation of the Model Description into the Sub-Space (Step 202)

For the transformation of the model description into the sub-space, a collective coordinate z (Equation 5) is introduced with:

$z = x - v_s{*}t$ (Equation 5),

~~[whereby]~~ **where** v_s indicates the velocity of a solitary wave. This solitary wave is an asymptotic solution of the model equations 1, 2 and 3, ~~[said]~~ **these** waves having a constant profile and propagating with a constant velocity v_s.

The transformed model description (step 203) (Equation 6) for a solitary wave derives as:

$$\frac{d^2}{dz^2} v + \frac{q_0}{\eta_0} \left(\frac{c_0^2 - (v - v_S)^2}{(v - v_S)^2}\right) \frac{d}{dz} v + \frac{q_0}{\tau\eta_0} \left(\frac{V_{eq}\left(\frac{q_0}{(v - v_S)}, u\right) - v}{(v - v_S)}\right) = 0$$

(Equation 6)

~~[with]~~ **where**:

$\frac{d}{dz} v$, $\frac{d^2}{dz^2} v$: a partial derivation of the first or, respectively, second order of the traffic flow velocity according to the collective coordinate z.

The transformed continuity equation (Equation 7) supplies the constant flow q_0 as secondary condition (Equation 8):

$$v \frac{d}{dz} \rho + \rho \frac{d}{dz} v - v_S \frac{d}{dz} \rho = 0 \qquad \text{(Equation 7)}$$

$$\rho(v - v_S) = q_0 = \text{const} \qquad \text{(Equation 8).}$$

3. Determination of the Regulating Model Description upon Employment of a Non-Linear, Structurally Variable Regulator (Step 204)

For regulating the transformed model description, a non-linear, structurally variable regulator is utilized [~~[5]~~]**(Lenz)** on the basis of the control properties.

To that end, the transformed model description (Equation 6) is presented as follows, taking Equation 4 into consideration:

$$\frac{d^2}{dz^2} v = f(v, \frac{d}{dz} v) + b(v, \frac{d}{dz} v)u,$$ (Equation 9)

$$f(v, \frac{d}{dz} v) = -\frac{q_o}{\eta_0}\left(\frac{c_0^2 - (v - v_s)^2}{(v - v_s)^2}\right)\frac{d}{dz} v + \frac{q_o}{\tau\eta_0}\left(\frac{V_{eq}(\frac{q_o}{(v - v_s)}) - v}{\tau(v - v_s)}\right),$$

(Equation 10)

$$d \quad q_o \quad V_{eq}(\frac{q_o}{(v - v_s)})$$ (Equation 11)

~~[with]~~ **where**:

f(v, dv/dz) or, respectively, b(v, dv/dz): imaging rules.

The design of the non-linear, structurally variable regulator ensues upon employment of the method of equivalent regulation ~~[[5]]~~**(Lenz)**.

The control rule (Equation 12) reads:

$u = u_e + u_n$ (Equation 12)

~~[with]~~ **where**:

u : regulator output quantity

u_e, u_n : equivalent or, respectively, non-continuous part of the regulator output quantity.

The following also applies:

$s = \lambda v + dv/dz$ (Equation 13)

$V_L(s) = (2)s^2$ (Equation 14)

~~[with]~~ **where**:

s : switch variable

λ : system parameter, $\lambda > 0$

V_L : Ljapunow-like function

$V_L(s)$: imaging rule.

The selection of the switch variable s ensues such that the system is stable for s=0 (sliding state).

The regulator output quantity u is determined such that the derivation of the Ljapunow-like function V_L according to the collective coordinate z is negative:

$dV_L/dz < 0.$ (Equation 15)

The sliding state s = 0 is described in equivalent fashion by disadvantageous/dz=0.

Taking the scaling (Equation 4) and the transformed model description (Equation 6) into consideration, the equivalent part of the regulator output quantity u_e is presented as follows:

$$u_e = \frac{1}{V_{eq}\left(\frac{q_0}{v - v_s}\right)} \cdot \left[v - V_{eq}\left(\frac{q_0}{v - v_s}\right) + + \frac{\tau}{v - v_s}\left[(v - v_s)^2\left(1 - \lambda \frac{\eta_0}{q_0}\right) - c_0^2\right] \frac{d}{dz} v \right]$$

(Equation 16)

The non-continuous part of the regulator output quantity u_n is presented as follows:

$$u_n = K \frac{\tau \eta_0 (v - v_s)}{q_0 V_{eq}\left(\frac{q_0}{v - v_s}\right)} \operatorname{sgn}(s) \qquad \text{(Equation 17)}$$

~~[with]~~ **where**:

K : system parameter, K > 0.

A regulated system in the sub-space is thus obtained (step 205).

4. Back-Transformation of the Regulator Model Description in the State Space of the System (Step 206)

For the back-transformation (step 206), the non-continuous part of the regulator output quantity u_n is neglected.

The back-transformation yields:

$$u_e = \frac{v - V_{eq}(q)}{V_{eq}(q)} + \frac{\tau}{V_{eq}(q)}\left[1 + \lambda \frac{\eta_0}{q_0} - \frac{c_0^2}{(v - v_s)^2}\right] \frac{d}{dt} v . \qquad \text{(Equation 18)}$$

Leaving the acceleration term dv/dt out of consideration, this ~~[being]~~ usually not **being** measured in practice, the following then derives:

$$u_e = \frac{v - V_{eq}(q)}{V_{eq}(q)} . \qquad \text{(Equation 19)}$$

The regulated system >traffic flow= in the original space of the technical system (step 207) is thus described by the following relationships (Equations 20, 2 and 21):

$$V_{eq}(\rho, u) = (1+u_e)V_{eq}(\rho) = v, \qquad \text{(Equation 20)}$$

$$\frac{d}{dt}\rho + \frac{d}{dx}q = \frac{d}{dt}\rho + \frac{d}{dx}(\rho v) = 0, \qquad \text{(Equation 2)}.$$

$$\frac{d}{dt}v + v\frac{d}{dx}v = -\frac{c_0}{\rho}\frac{d}{dx}\rho + \frac{\eta_0}{\rho}\frac{d^2}{dx}v. \qquad \text{(Equation 21)}$$

A local stability analysis of the regulated system in the original space exhibits the following properties of the regulated system:

The regulated system exhibits a stable behavior with respect to arbitrary disturbances in the entire state space of the technical system. [

]The homogeneous and stable state of the regulated system (ρ_{hom}, q_{hom}, v_{hom}) that occurs due to the non-linear and structurally variable control corresponds to the spatially average starting conditions of the system quantities (ρ, q, v). [

]The regulating variable supplies maximum values (maximum control interventions approximately 25 km/h) that can be applied to the real system >traffic flow=.

Figure 3 schematically shows how, upon employment of the regulated model of the system >traffic flow=, the real system >traffic flow= is homogenized.

At a predetermined location 301 of a monitored traffic flow 302, the state quantities (ρ, q, v) of the traffic flow 302 are measured at predetermined time intervals Δt. The measurement is started at prescribable time t = 0s.

The measured starting state quantities of the real system are ρ_{Start}, q_{Start}, v_{Start}. [

]The measured state quantities (ρ, q, v) are applied to the regulated model of the system. When a disturbance of the real system occurs, the measured state quantities ($\rho_{disturb}$, $q_{disturb}$, $v_{disturb}$) change. **Depending** ~~[Dependent]~~ on the currently supplied state quantities of the system ($\rho_{disturb}$, $q_{disturb}$, $v_{disturb}$) and on the starting

state quantities (ρ_{Start}, q_{Start}, v_{Start}), the regulated model determines the regulating variable v_{rated}. [

]This is displayed to a traffic participant 304 with the assistance of a traffic guidance system 303. At a time t_1, the real system again reaches the stable starting condition (ρ_{Start}, q_{Start}, v_{Start}).

A few alternatives of the invention are indicated below:

One alternative approach for the velocity in the equilibrium is:

$$V_{eq}(\rho) = V_0\left(\left(1 + \exp\left(\left(\frac{\rho}{\rho_{max}} - 0.25\right) / 0.06\right)\right)^{-1} - (1 + \exp(-0.25 / 0.$$

~~[whereby]~~ **where** $V_0 = 95km / h$ and $\rho_{max} = 125Fz / km$ ~~[apply]~~.

The acceleration equation can also be replaced with a different approach, insofar as the characteristic properties such as instability in the medium density range and the occurrence of a solitary wave as asymptotic solution are assured.

The ~~[following publications were cited in this document:]~~ **above-described method and arrangement are illustrative of the principles of the present invention. Numerous modifications and adaptations thereof will be readily apparent to those skilled in this art without departing from the spirit and scope of the present invention.**

~~[[1]: Kerner, B.S., et al. AStructure and parameters of clusters in traffic flow@, Phys. Rev. E50 (1), pp. 54-83, 1994.]~~ **ABSTRACT**

~~[[2]: Kühne, R., Pal, S.K., AStraßenverkehrsveeinflussung und Physik der Phasenübergänge@, Physik in unserer Zeit, Volume 15, No. 3, pp. 84-92, 1984.~~

~~[3]: Zackor, H., et al., AUntersuchungen des Verkehrsablaufs im Bereich der Leistungsfähigket und bei instabilem Fluß@, Forschung Straßenbau und Straßenverkehrstechnik, No. 524, 1988.~~

~~[4]: Cremer, M. et al., AEinsatz regelungstechnischer Mittel zur Verbesserung des Verkehrsablaufs und Straßenverkehrstechnik, No. 307, 1980.~~

~~[5]: Lenz, H., Berstecher, R., Lang, M., >Adaptive Sliding-Mode Control of the Absolute Gain@, IFAC Nonlinear COntrol Systems Design Symposium, Enschede, Netherlands, 1988.~~

~~Abstract~~

~~METHOD AND ARRANGEMENT FOR DETERMINING A REGULATING VARIABLE OF A TECHNICAL SYSTEM THAT IS DESCRIBED WITH A PREDETERMINED MODEL DESCRIPTION IN A PREDETERMINED SPACE~~

~~A method and an arrangements [sic]]~~ **A method and an arrangement** are disclosed for determining a regulating variable of a technical system[~~, whereby the system~~] **that** is described with a predetermined model description in a predetermined space. In the method, the model description of the technical system is transformed into a sub-space of the space. [~~Thereat, a~~] **A** regulator model description is determined from the transformed model description upon employment of a prescribable non-linear regulator model. The regulator model description is transformed back into the space of the model description. The regulating variable is determined upon employment of the back-transformed regulator model description.

~~[Figure 2]~~

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FIG 1

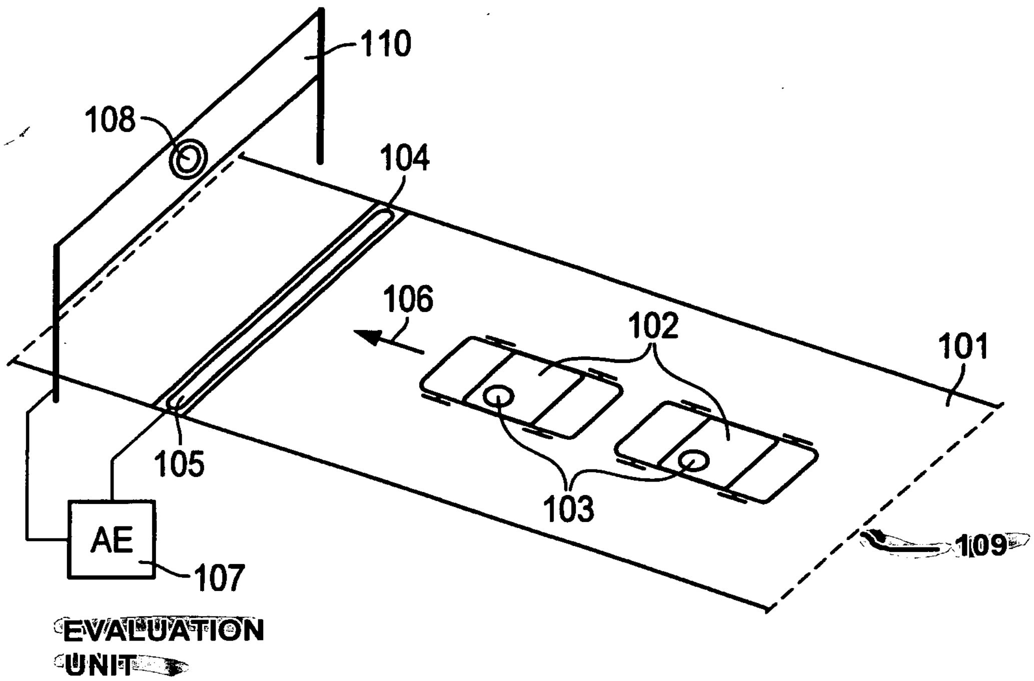

FIG 3

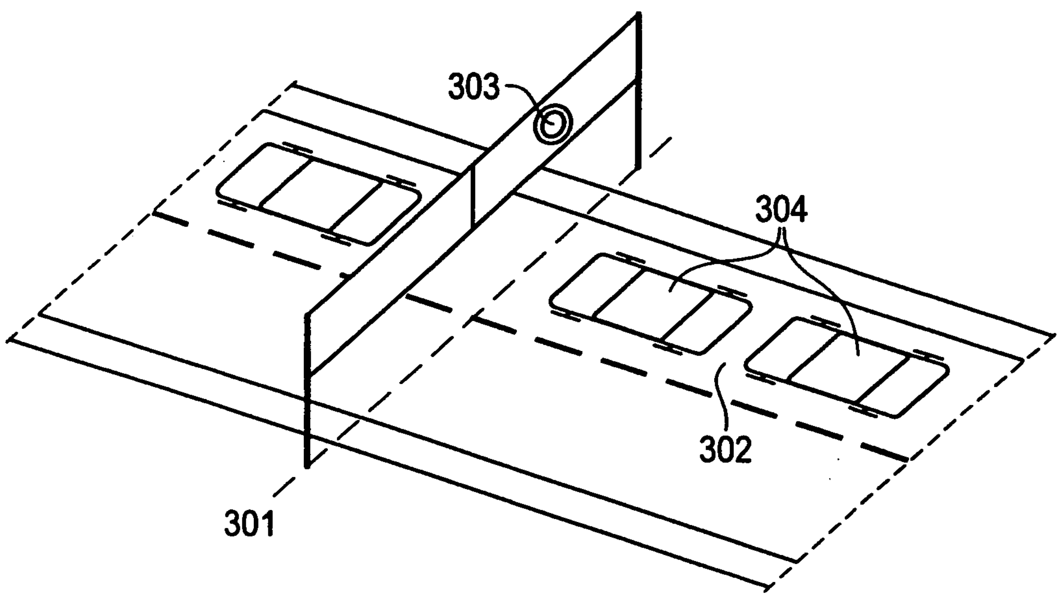

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FIG 2